CEMENT AND LIME MANUFACTURE

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The German Cement Industry.

FOLLOWING an investigation of the cement industry in the British and American Zones of Germany, a report by Mr. G. G. J. Davis (Britain) and Mr. A. Swayze (United States) has been published (price 2s. 6d.) by His Majesty's Stationery Office. Among the points mentioned in the report are the following.

In some cement works combination drying and grinding mills of types not used in England or the United States had been installed. Raw mix finenesses were relatively coarse, emphasis being placed on output and low power consumption rather than on increased fineness. Many factories still operate vertical kilns, and the quality of the clinker from these kilns is poor. In rotary kilns the dry mix is nearly always nodulised, using 8 to 10 per cent. of water; this practice may have some advantage. Clinker cooling is generally done in rotary coolers under the rotary kilns. A few coolers of a special pressure type were seen, but their performance was usually reported to need improvement. The proportioning of clinker and gypsum was crude, no proportioning by weight being seen in the 26 works visited. In the proportioning of blastfurnace slag with clinker for eisenportland and hochofen cement the same roughness of control was found. Practically all finish grinding was done in open circuit, only one plant making use of air-separation to circulate coarse material back to the grinding mill. The ordinary cements were somewhat coarser than is considered normal in Britain and America. Packing of cement was almost exclusively in paper bags. Normal cement was packed in 2-ply bags and high-strength cement in 4-ply bags. Producers occasionally reported a few bulk supplies during the last years of the war, but stated that the practice was unpopular with users.

No new cements have come to the production stage, although a "sursulphate" cement was reported to have good properties when ground very fine in a laboratory mill. At all factories, even those normally producing only ordinary Portland cement, blastfurnace slag was added to the clinker if the factory was within 150 kilometres of a blastfurnace. The survey showed that quantity had been increased during

the war to the distinct disadvantage of quality. Chemical control methods, and equipment for obtaining it, were inferior to those in use in the United States and Britain in most of the factories seen. Also the quality of the clinker was poorer due to efforts to save fuel.

Machinery for drying and grinding developed in the past ten years may merit further investigation, especially the Humboldt type of mill described later. Special bricks for lining the hot zones of rotary kilns have merit.

Raw Materials.

At nearly all the works visited the raw materials consisted of a fairly hard high-calcium limestone interspersed with a softer marl of lower lime content, similar to the English Lias formation. Some factories in the Ruhr produced Portland cement clinker from blastfurnace slag and a high-calcium lime (95 to 98 per cent. $CaCO_3$). In a number of quarries instead of dumping the earth stripping in piles it was placed smoothly on the quarry floor, and in a number of cases good crops were being grown on this soil.

Two ingenious feeders for hammer mills operating on sticky materials consisted of alternate stationary and movable steel bars running between the dump pit and the mouth of the crusher. The movable bars operated with an elliptical motion, moving forward above the level of the stationary grid and back below it. Provision was made for the disposal of the fine dry stone which dropped between the bars. Feed to the mill was uniform.

Grinding Raw Materials.

A drying-grinding mill produced by Humboldt-Deutz, at Koln, consisted of a ball mill with a diameter about 50 to 60 per cent. of the length, air-swept by hot gas from a separately-fired coal furnace. A large induced-draught fan circulated the gas through the mill to a novel type of air separator, a cyclone dust collector, and back to the mill. A similar fan drew fresh hot gas into the system by exhausting waste gas from the cyclone to the atmosphere through either a large bag filter or an electrical precipitator. In one case a rain tower was used for cleaning the exit gas. Fresh gas from the furnaces entered the mill at a temperature 500 to 600 deg. C. Exit gases from the system were reported to have a temperature of 80 to 100 deg. C. The proportions of fresh to circulating gas ranged from 1 : 3 to 1 : 4. No reliable information was available on gas velocities. The air separator had no moving parts. It consisted of a typical conical shell below a short cylindrical section with a flat top and an exit pipe at the top centre. The interior of the separator has a smaller and flatter cone open at the top, but closed at the bottom by four small trap doors. Movable blades set radially for maximum output and lowest fineness occupied the space between the top of the inner cone and the upper section of the shell. The dust-laden gases entered the separator through a vertical pipe at the bottom, and dropped their coarser particles, due to the greater area in the conic section, on to the inner surface of the outer cone, from which they ran by gravity back to the mill. The finer dust passed up through the stationary

blades, down into the inner cone, and thence up the centre pipe to the cyclone collector. The blades could be shifted by a lever mechanism to any angle from radial to almost tangential, thereby decreasing the flow of gas and increasing the fineness of the product. The main objection to this equipment is the cost of the structure required to house it, since it needs a stable building of considerable height. The main fans had motors ranging from 110 to 185 kw., and these were mounted on the upper floors.

Another drying-grinding unit, namely the Losche mill produced by Carl von Grüber at Berlin, is a vertical edge-runner unit with rotating base table, identical with a unit coal pulveriser produced by International Combustion, Ltd., in England. It is also swept by hot gas, either from separate coal-fired furnaces or the waste gas from rotary kilns, and accomplishes both drying and grinding. However, where relatively high finenesses are required, wear of the rotating table and rolls is reported to be rapid. The same objection applies to its use in pulverising coal, where it is also employed. The most satisfied user interviewed claimed little upkeep on a dry mix, but at this plant the fineness was 20 to 22 per cent. residue on a 4,900 metric sieve (178 meshes per inch). When the mill can be run on a load of material sufficient to act as a cushion between the rolls and the table, wear should be decreased but the fineness of the product would not be as good. The mill has no application where the wet process is used.

The Polysius "Pfeiffer" mill consists of a short ball mill having a ring of parallel longitudinal slots through the lining and shell near the centre line of the mill. The dimensions of the shell varied with the capacity desired, but averaged 6 ft. 6 in. diameter by 21 ft. long. Dry rock was fed in at one end and the ground product discharged through the slots into a short housing over a screw conveyor. The product was elevated to an air separator, from which the coarse rejects were returned to the other end of the mill. The position of the slots seemed to be still in the experimental stage, since they ranged from the centre of the mill in some cases to about 60 per cent. of the length away from the feed entrance in others. In one case the shell was perforated by several rings of slots from one end to the other, but this was reported as less satisfactory. The principal objection seemed to be that the slots weakened the lining and the shell. Power consumption for the three types of mill were low, ranging from 8 to 15 kw. per ton.

Preparation of Mix for Burning.

With one exception, the dry-process rotary kilns were fed with a dampened nodulised feed containing from 8 to 15 per cent. of water. Nodulisation of the dry mix requires heat to evaporate the water used for nodulising, but there is generally more heat in exit bases from dry kilns than can be used to advantage otherwise. Where there is clay-like material in the mix the nodules do not reduce to powder on drying, but more or less hold their original form. This type of grain does not cascade when CO_2 begins to be evolved, and a saving in fuel consumption may therefore result. There should also be materially less dust loss.

Kiln Types and Operation.

Vertical shaft kilns are still popular in Germany. Twelve out of the 28 plants visited had vertical kilns in working condition, while six plants had no other burning equipment. At all these plants the management claimed equal quality from the shaft-kiln product, regardless of the high variability in clinker quality which ranged from partially-burned raw mix through good clinker to fused material. Where ash from the larger fuel particles had combined with the mix, the clinker was badly slagged. In many plants the slow cooling which resulted after the fuel was consumed caused the clinker to dust badly, due to inversion of the di-calcium silicate from the beta to gamma form. The air for combustion is blown into these kilns at two positions. One set of tuyeres is at the base and serves to cool the burned product and preheat the air for combustion. Another set is around the shell of the kiln higher up, giving roughly uniform combustion conditions over the kiln section. The dampened mix in nodule or lump form is distributed automatically at the top of the kiln, but requires an attendant at almost every kiln to keep the distribution of the fine and over-wet coarse material uniform. Combustion begins very close to the top surface, and apparently causes a high temperature to be reached very rapidly. Some difficulty is reported in sticking of the load to the sides of the kiln when an excess of fuel is used. Dust losses are variable, but usually moderate. The principal advantage of this type of kiln is its low consumption of a low-grade fuel, which was reported to range from 17 to 20 per cent. by weight of clinker. Anthracite screenings or coke breeze were used. Bituminous coal was not satisfactory due to heat losses which would result from the distillation of the volatile matter. While producers claimed equal quality with rotary kiln cement, practically all their cement was marketed as meeting only the lowest strength requirements in German specifications.

Coal consumption in the standard dry-process rotary kilns was reported to be 22 to 25 per cent. The manufacturers in general appeared to be satisfied with lighter burning than is found in America or Britain. The determination of the free-lime content of clinkers or cement was rarely if ever made.

Most producers favoured a uniform kiln diameter, with only enough enlargement of the burning area to compensate for the increased coating formed in this zone.

One wet-process works used a Miag calcinator and two used the Dyckerhoff spray system for driving out part of the water from the slurry and thus utilising the excess temperature in the kiln gases. Both methods give rise to large dust losses unless used in conjunction with a precipitator or other means of arresting the dust lost. At another works a Miag calcinator had been discarded due to dust losses.

Coal consumption in the wet-process works visited averaged 3 to 4 per cent. higher than at dry-process works.

A new type of kiln resembling the Dwight-Lloyd sintering grate for metallic ores was reported in use at a works in the Russian area and at a works in the French area at Drottinghausen. These were not visited. The reported method

of operation was as follows. Clinker previously burned was crushed and screened into three fractions. The finest portion, consisting of unburned material, was returned to the stream of dry raw mix and fuel being fed to the noduliser. The next finest portion, consisting of particles from 6 to 8 mm. in size, was placed on the travelling grates, and to protect them from the heat a layer of 15 to 20 in. of nodulised material plus fuel was superimposed. The grate then moved under an ignition hood, where an auxiliary flame from a coal or gas fire ignited the mixture within a minute or two. Passage of the grate under the hood required enough time to start good combustion of the fuel in the upper layers. From here on combustion is induced by a series of draught boxes under the grates, and continues until all the fuel is consumed and the clinker is cooled. Low fuel costs were reported, and an output of 10 tons of clinker per day per square metre of grate is claimed.

Rotary Kiln Linings.

Two new types of lining blocks were seen which merit trial. American producers of linings have been advocating the abandonment of the conventional shapes, in which the long dimension of the blocks is set in a circle, for an arch type of brick in which the long dimension of the base is laid longitudinally in the kiln. German producers have already adopted this practice for fireclay, high alumina, and magnesite blocks, and have evolved an interesting modification. End blocks for junction with existing linings have 90 deg. ends, but the other face is inclined 15 deg. from the vertical. All the normal blocks have a parallel slope on both up-kiln and down-kiln faces. Alternate end blocks around the kiln section have opposite inclinations, and alternate longitudinal rows are laid so that the slope of each row is reversed. This would appear to give a better key for the bricks, but might make repairs more difficult. Magnesite linings of these shapes are manufactured by the Austro-American Magnesite Co., Radenthein, Carinthia, Austria, and marketed under the name " Radex." Both the magnesite grain and bonding agent are dead-burned. This company has produced a modification to compensate for the inability of magnesite linings to take the usual kiln coating. A fireclay brick 5 cm. thick is laid under four rows of magnesite bricks, while the fifth row is set 2½ to 3 cm. closer to the kiln shell and supported by a cement-clinker mix. This arrangement of built-in grooves prevents sliding of the kiln load on the bricks, thus preventing wear. The thickness of the magnesite bricks in the lining seen was 18 cm., giving a total thickness of 23 cm. except at the grooves.

The practice of placing thin steel plates between bricks in magnesite linings has been given up, and the bricks are now set in a mortar consisting of magnesite brick dust and waterglass. Producers report excellent life for the method when the kilns are of sufficient rigidity. Several kilns had stiffening bands in the burning area, evidently to lessen flexure of the shell.

Another development was a clinker-cement devised by Dr. Fritz Koeberich, of the Heidelberger-Leimen Portland Cement Co. Linings of Portland cement linker bonded by cement have not been satisfactory due to rapid decomposition

of the brick and loss of about half the thickness when the kiln is cooled. The Koeberich block is claimed not to develop this fault, and to have a life of a year or more. The bricks are made from graded Portland cement clinker bonded with Portland cement, and moulded by tamping or by pressure and vibration. A mix of 1 part cement to 3½ to 4 parts of clinker is used. The form of the bricks is the arch type. After curing, they are placed in a ceramic kiln and subjected to a temperature of 1,400 to 1,500 deg. C., which converts the hydrated cement compounds back to the unhydrated clinker minerals. In this form the structure of the brick is not affected when the kiln is cooled. Both clinker and cement must be of low dicalcium silicate content in order to prevent dusting and consequent disintegration of the bricks during the slow cooling period in the ceramic kiln. It would appear that this method has considerable merit.

New Cements.

With the exception of five plants which produced " Höchstwertig " (highest-strength) Portland cement, no new products were found of the Portland type. A high-strength cement of non-Portland type was reported by a company which had experimented with a " sursulphate " cement. This product consisted of 80 to 84 per cent. of high-calcium granulated blast-furnace slag, 15 per cent. of dead-burned gypsum, with 1 to 5 per cent. Portland cement clinker as an activating agent. An additional requirement was that the slag should preferably contain 18 per cent. or more alumina (Al_2O_3). The mixture was ground to a very high fineness in a laboratory mill. None of the cement had been made in the plant. This cement was reported to develop a compressive strength above that of the highest grade Portland cement, and in one year, when stored in water, a tensile strength almost twice that of Portland cement. The product was said to have low heat of hydration, and very low expansion and contraction values in wet and dry storage. One prism broken at the age of one year had strengths of 1,280 lb. per square inch in flexure and 10,250 lb. per square inch in compression. The exterior of the prism was somewhat soft, and yellowish-green in colour. The interior was very hard, and greenish-black in colour. Information from other sources revealed that " sursulphate " cements made in other countries had a good record for stability under water, but did not stand weathering at the water-line or above. Roads and similar exposed surfaces are reported to become chalky at the surface and to withstand wear poorly.

Trass Cement.

The production of trass cement in the zone declined from 200,000 tons in 1937 to 5,340 tons in 1944. In 1938 the auto roads in the Eifel area had begun to show scaling and other signs of distress. It was understood that trass cement had been used in at least some of these sections. During the investigation it was found that some of these roads had been given an asphaltic coat. Others in the same region were showing some scaling and a small amount of ravelling at joints. While it is not safe to conclude that these stretches also contained trass cement, this area is the only one in which the auto roads show any surface distress due to traffic or weathering.

A Formula for Proportioning Raw Materials.

IN an article in " Cemento Hormigon " for March and April, 1946, Sr. A. V. Ortuño examines and develops the formula

$$CaO = x\,SiO_2 + 1{\cdot}65\,Al_2O_3 + 0{\cdot}34\,Fe_2O_3 \quad .. \quad .. \quad .. \quad .. \quad (1)$$

or, in terms of carbonates

$$CaCO_3 = x\,SiO_2 + 2{\cdot}95Al_2O_3 + 0{\cdot}6Fe_2O_3 \quad .. \quad .. \quad .. \quad .. \quad (1')$$

It is claimed that these formulæ, which represent the combination of raw materials, forecast the hardening characteristics of a Portland cement. Special cases of these formulæ apply to cements which do not contain tricalcic aluminate but in one case have a preponderance of tetracalcic aluminoferrite and are relatively stable in the presence of sulphates and sea-water. This embraces the problem in its widest aspect, since cement must possess (*a*) mechanical resistance, denoted by the coefficient x in the formulæ, which also determines its stability of volume when in large masses, and (*b*) resistance to attack by chemical agents which depends on the ratio of Al_2O_3 to Fe_2O_3.

In view of the complex nature of the raw materials used in the manufacture of cement, it is impossible to obtain a single formula which provides all the necessary data regarding hardening, fluxes, and the ratio of alumina to oxide of iron; a choice must be made in favour of one characteristic, the remaining characteristics being settled automatically within certain limits. The present study is limited to the proportioning of the raw materials for Portland cement, that is, when the ratio of Al_2O_3 to Fe_2O_3 is greater than 1·56.

Methods of Proportioning.

ANALYTICAL METHOD.—The simplest and most usual case is the establishment of the ratio in which clay and, say, limestone, have to be mixed in order to obtain a crude product which, when ground, is suitable for making a clinker conforming to the proportioning formula. Assume the chemical analysis is

	Clay	Limestone
Loss on ignition ..	*Pa*	*Pc*
SiO_2	*Sa*	*Sc*
Al_2O_3	*Aa*	*Ac*
Fe_2O_3	*Fa*	*Fc*
MgO	*Ma*	*Mc*

Sc parts of silica contained in 100 parts of limestone require, according to the formula, *xSc* parts of CaO, and *Ac* and *Fc* parts of alumina and iron oxide require 1·65 *Ac* and 0·34 *Fc* parts of CaO respectively. Thus the remaining lime is $Cc - (xSc + 1{\cdot}65Ac + 0{\cdot}34Fc)$. In *M* parts of limestone the quantity of calcium required according to the foregoing is

$$M\,[Cc - (xSc + 1{\cdot}65Ac + 0{\cdot}34Fc)]$$

Similarly, *Ca* parts of CaO in the clay would require $\frac{Ca}{x}$ parts of silica, $\frac{Ca}{1{\cdot}65}$ parts

of alumina and $\frac{Ca}{0{\cdot}34}$ parts of ferric oxide. Thus there remains an excess of each of these oxides equivalent to a total of $(xSa - Ca)$ parts of CaO for the silica, $(1{\cdot}65Aa - Ca)$ for the alumina, and $(0{\cdot}34Fa - Ca)$ for the ferric oxide, say a total of N parts. Thus for a lime saturation for the elements of the clay affected by the coefficient x,

$$\frac{M}{N} = \frac{(xSa + 1{\cdot}65Aa + 0{\cdot}34Fa) - Ca}{Cc - (xSc + 1{\cdot}65Ac + 0{\cdot}34Fc)}$$

By substituting for C, A, F, and S the numerical values determined by analysis, and for x the value corresponding to the hardening desired, the problem can be solved rapidly. The calculations must be continued to ensure that the cement complies in other respects with the specification. If Qa and Qc are the percentages of clay and limestone respectively which are mixed in accordance with the foregoing calculation, and Pa and Pc the losses through the calcining of these materials, it can be deduced that 100 parts of clinker contain

$$100 - \frac{QaMa + QcMc}{\frac{QaPa + QcPc}{100}} \text{ parts of MgO.}$$

The value determined from this expression should be less than the maximum amount permitted by the specification. (Note: this amount is 5 in the Spanish specification, and 4 in the British Standard.) There is no analogous calculation for assessing the SO_3 content, since all the sulphur originally in the raw materials is not usually contained in the clinker, some having been carried off in the hot gases.

To confirm that Qa and Qc are suitable, there remains to be fulfilled the condition that, according to the Spanish specification, $\frac{SiO_2}{Al_2O_3} \geq 2{\cdot}5$. By similar deduction to that for the magnesia equation,

$$\frac{SaQa + ScQc}{AaQa + AcQc} \geq {\cdot}5.$$

Similarly the expression for the hydraulic modulus can be derived.

In most cases it is not possible to give the foregoing expressions with accuracy, owing chiefly to the action of the fuel used for burning the raw material and to the fact that some of the latter is carried along by the gases of combustion.

When the available materials are such as to make it impossible to comply with one of the foregoing requirements, for example the magnesia content, it is necessary to add a material of the same type but lower in MgO content in order to dilute the magnesia contained in the binary mixture. The addition of other materials as correctives may improve the fluxing qualities or, in the case of iron oxide, increase the resistance to sulphate attack.

GRAPHICAL METHOD.—This method is based on Grün's diagram. Consider a system of rectangular co-ordinates (*Fig.* 1) the abscissæ of which represent the percentage of silica and the ordinates the percentage of CaO. On the line AA

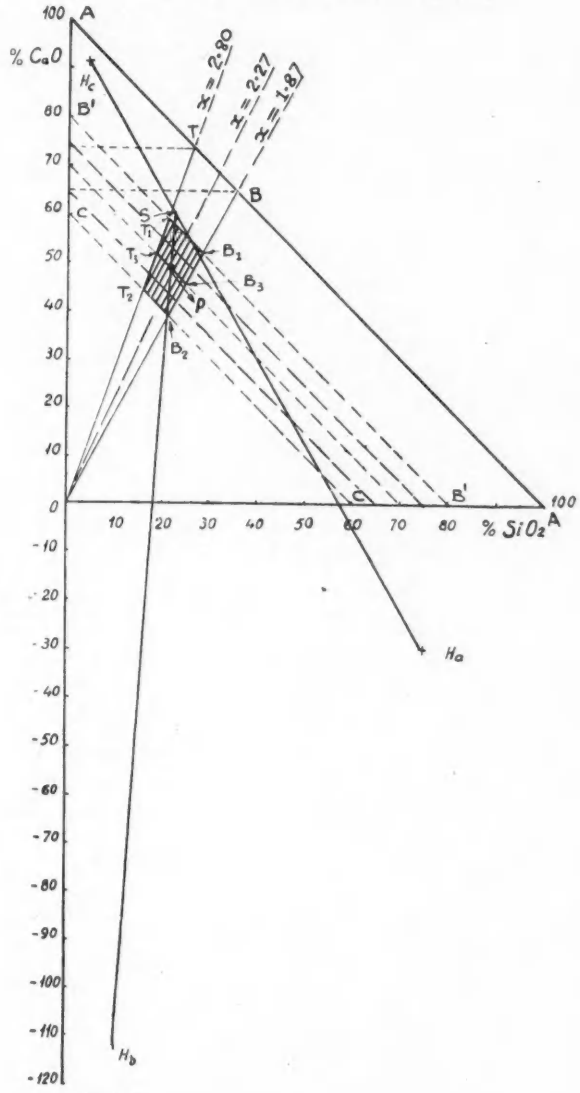

Fig. 1.

are found all the possible combinations of CaO with SiO_2. The calcium silicates concerned are bicalcium and tricalcium, which respectively have the percentage compositions (0·65 CaO + 0·35 SiO_2) and (0·7359 CaO + 0·2641 SiO_2).
These are represented by the points B and T on AA, and all possible mixtures of both combinations are represented by points between B and T.

All the components of the clinker are not composed of lime and silica, as there are also calcium aluminate and aluminoferrite, magnesia, calcium sulphate, etc., and as the amount of these materials is from 20 to 40 per cent., the amount of lime and silica together is from 80 to 60 per cent. Thus the line AA is displaced parallel to itself to any position between B'B' and CC. By joining B and T to the origin, the area $T_1B_1B_2T_2$ contains the points corresponding to those proportions of CaO and SiO_2 and the fluxes which with adequate firing may produce a standard Portland cement.

By dividing T_1B_1 into a number of equal parts (for example, eight), and B_1B_2 into, say, four equal parts, the grid indicated on *Fig.* 1 can be drawn. At each intersection in this grid there is a corresponding value of x; in *Fig.* 1 three numerical values are shown. It is easy to read from the diagram the composition corresponding to any point in the grid. For instance, at point P the sum of the calcium silicates is 70 per cent., and therefore the fluxes and other materials constitute 30 per cent. From this the coefficient relating to the hardening capacity may be deduced by the formula $\frac{\Sigma S}{100 - \Sigma S} = \frac{70}{30} = 2{\cdot}33$. Furthermore, as the ratio of T_3P to B_3P is $3\frac{1}{2} : 3\frac{1}{2}$, the clinker represented by P contains the calcium silicates in equal proportions.

To each raw material there corresponds a point on the triangular diagram according to its silica and lime content. It must be remembered that there must be deducted from the original ordinate the CaO which has not combined with the SiO_2 of the clay, but which reacts with the alumina and ferric oxide. From analytical data relating to calcined materials, and making allowance for the stoichiometric ratio in which the iron and calcium oxides combine to form tetracalcium aluminoferrite, it may be deduced that the CaO corresponding to each unit of Fe_2O_3 is $\frac{224}{157{\cdot}5} = 1{\cdot}4$. Since to form aluminoferrite the Fe_2O_3 requires a quantity of alumina equivalent to $\frac{102}{159{\cdot}7} = 0{\cdot}64$, the remaining alumina capable of forming tricalcium aluminate will be $Al_2O_3 - 0{\cdot}64Fe_2O_3$, and the lime corresponding to this is given by $1{\cdot}65\ (Al_2O_3 - 0{\cdot}64Fe_2O_3)$.

If the co-ordinates of each of the given components are plotted, there is obtained, if the proportioning is binary, two points representing the materials to be proportioned. Assume these points are Ha and Hc for the clay and limestone respectively. A straight line from Ha to Hc (*Fig.* 1) may or may not pass through the normal clinker zone indicated by the grid. If it does, a point R on this line is selected and the lengths RHa and RHc are measured. The proportions in which the clay and limestone should be mixed are $\frac{\text{RHc}}{\text{RHa}}$. From the position of R

the percentage of fluxes in the burnt product is known, and therefore the percentage of silicates and the hardening qualities. The reciprocal ratio of the two silicates (the value of x) is also known, and therefore whether the cement will be normal or rapid hardening is determined.

When the line HaHc does not cut the normal zone, or does so near one corner, the necessity of adding a third material (ternary proportioning) to correct the mixture is indicated. Frequently there is a lack of fluxes, that is HaHc cuts through the area TT_1B_1B, in which case bauxite is employed as a corrective. Consider as an example three materials having the following analyses:

	Clay Per cent.	Limestone Per cent.	Bauxite Per cent.
Loss on ignition ..	12·1	42·3	0·7
SiO_2	75·4	4·1	10·3
Al_2O_3..	18·2	1·3	62·6
Fe_2O_3	6·2	0·6	24·3
CaO	0·2	94·4	—

First determine the point Ha representing the clay.

CaO required to combine the $Fe_2O_3 = 6{\cdot}2 \times 1{\cdot}4 = 8{\cdot}8$

CaO required to combine the $Al_2O_3 = 1{\cdot}65\,[18{\cdot}2 - (0{\cdot}64 \times 6{\cdot}2)] = 21{\cdot}3$

Residual CaO $= 0{\cdot}2 - 8{\cdot}8 - 21{\cdot}3 = -29{\cdot}9$.

The co-ordinates for the clay are therefore $x_a = +75{\cdot}4$ and $y_a = -29{\cdot}9$. Similarly, the co-ordinates for Hc representing the limestone are $x_c = +4{\cdot}1$ and $y_c = +91{\cdot}65$, and for Hb representing the bauxite are $x_b = +10{\cdot}3$ and $y_b = -111{\cdot}56$.

A point P within the normal area (*Fig.* 1) is now selected. This gives a clinker containing 70 per cent. of silicates (with equal proportions of each silicate), and the coefficient x in formula (1) is 2·27. Join Hb to P and project to meet HcHa at S. The quantities of each material required to form the crude mixture, which after clinkerisation gives a product with the characteristics represented by P, are limestone = SHa = 103·5 parts = Qc; clay = SHc = 37 parts = Qa; bauxite = Sha + SHc. $\frac{PS}{HbP} = 9{\cdot}9$ parts = Qb. As the amounts given refer to the calcined materials, the equivalent quantities of each raw material required can be calculated, making allowance for the loss on ignition of each. Thus

Clay: $Qa' = \frac{37 \times 100}{100 - 12{\cdot}1} = 42$ parts.

Limestone: $Qc' = \frac{103{\cdot}5 \times 100}{100 - 42{\cdot}3} = 180$,,

Bauxite: $Qb' = \frac{9{\cdot}9 \times 100}{100 - 0{\cdot}7} = 10$,,

SIMPLIFIED METHOD.—Many cement works (in Spain) proportion the materials by the control of the $CaCO_3$ content only, a value for which is fixed from experience. To produce a uniform product this method can only be used when the composition of the raw materials does not vary.

Since the lime factor depends on the proportion of $Al_2O_3 + Fe_2O_3 + SiO_2$ present, it is thought by some to be more convenient to prepare the raw material on the basis of a definite ratio between the percentage of carbonate and the sum of the percentages of these three oxides. This method is applicable if the composition of the raw materials is constant, because for a given value of the sum of the "acid oxides" the comparative amount of each oxide may vary considerably, and the coefficient of saturation of each is different. Assuming that, for purposes of a check, the fundamental condition of uniformity of composition relates only to the determination of the $CaCO_3$ content, formula (1′) can be used, thereby avoiding the empirical selection of a $CaCO_3$ factor. The latter can therefore be fixed by giving to x a value between 3·34 and 5·0, according to the properties required.

In the wet method of manufacture, two slurries having equal percentages of water and similar carbonate contents have the same specific gravity. Thus $\frac{V_1}{V_2} = c - \frac{c_2}{c_1 - c}$, where V_1 and V_2 are the necessary volumes of slurries with high and low carbonate content, c_1 and c_2 per cent. respectively, and c is the required percentage of carbonate. Since it is difficult to maintain the percentage of water constant in successive batches, other calculations must be made to obtain the exact proportions.

Let *Ps* denote the drier slurry, *Ph* the slurry containing most water, and a and d the percentage of water and specific gravity respectively. Then ($c_1 \times$ weight of batch No. 1 of *Ps*) + ($c_2 \times$ weight of batch No. 2 of *Ps*) = ($c \times$ total weight of *Ps*). The weight of volume V_1 of the first slurry is $V_1 \times d_1$, and if 100 gm. of *Ph* contains $(100 - a)$ gm. of *Ps* ($V_1 \times d_1$) gm. of *Ph* contains $\frac{V_1 d_1 (100 - a_1)}{100}$ gm. of *Ps*. By substituting in the general equation $d_1.V_1(100 - a_1)c_1 + d_2.V_2(100 - a_2)c_2 = d_1.V_1.(100 - a_1)c + d_2.V_2(100 - a_2)cd_1V_1(100 - a_1)c_1 + d_2V_2(100 - a_2)c_2 = d_1V_1(100 - a_1)c + d_2V_2(100 - a_2)c$.

Thus $\frac{V_1}{V_2} = \frac{d_2(100 - a_2)(c - c_2),}{d_1(100 - a_1)(c_1 - c)}$

and $V_1' = \frac{d_2(100 - a_2)(c - c_2)}{d_2(100 - a_2)(c_1 - c_2) + d_1(100 - a_1)(c_1 - c)}$ .. .. .. (2)

where V_1 is the volume of slurry having the higher carbonate content which must be mixed with $(1 - V_1)$ of the slurry having the lower carbonate content to obtain unit volume of slurry with a carbonate content of c per cent.

A further simplification can be introduced, owing to the mutual dependence of a and d. Between these two variables there exists a mathematical ratio. The latter can be expressed by a first degree equation $d = m - na$. Having calculated the parameters, the values $m = 2{\cdot}4$ and $n = 2{\cdot}10^{-2}$ are obtained, whereby $a = 120 - 0{\cdot}5 \times 10^2 \times d$. By substitution in (2), and by representing $(d^2 - 0{\cdot}4d)$ by D, and reducing, $V_1 = \frac{1}{1 + \frac{D_1(c_1 - c)}{D_2(c - c_2)}}$ .. .. .. (3)

The advantage of formula (3) compared with (2) is that the determination of the water in the slurry is not needed.

Critical Study of Formulæ.

The chemical constitution, and therefore the properties, of a cement do not depend only on the composition and proportions of the raw materials but also on such factors as the intensity and duration of burning, the duration of the cooling period, losses of raw material escaping with the gases, the action of the fuel ash, and chemical and physical state of the components of the raw materials. The effects of the intensity of the burning process and the duration of the burning and cooling periods are not within the scope of the present article.

The losses due to the powdered raw material being carried off by the gases of combustion as dust or otherwise are obvious. The chemical and physical state of the constituents have well-defined effects on the proportioning. For example, the combination with CaO of the SiO_2 contained in the raw material as a silicate is not difficult under normal conditions, and neither is that of the free hydrated silica that may be included with it. This does not apply to quartz. It is logical to suppose that the capacity of the silica to react depends on the area exposed to the reaction, and therefore on the fineness of the raw material.

In the kiln the grains of SiO_2 encased in an " atmosphere " of CaO produce around themselves an initial coating of SiO_2. CaO and, superimposed on the latter, another of $SiO_2.2CaO$ and $SiO_2.3CaO$. The result is that the clinker granule presents a heterogeneous structure if it is not possible for all the silica to be dissolved. This means that if part of the CaO remains uncombined the clinker is liable to expansion and its strength, heat of hydration, rate of hardening, and other properties depending on the total and relative proportion of silicates, consequently change. To allow for these effects a calcining test consisting of heating the crude mixture for 20 minutes at 1050 deg. C. and determining the insoluble residue of HCl and Na_2CO_3 can be made. The calcination residue R is substituted in the empirical equation $A = \frac{3{\cdot}7 \times \text{clay}}{\text{carbonate} \times (R + 7{\cdot}6)}$, which gives a measure of the characteristic termed the " aptitude for calcination." A definite validity might be attributed to A if R depended only on the temperature attained in the test. It is likely that the variation of the latter as a function of the working temperature is not a function of the first degree, since the reactions take place in a slurry and viscosity, which to a certain extent determines the speed of the reaction, is a log-log function of temperature.

However, of all the factors which militate against the clinker having the composition deduced from the proportions of the raw materials, the action of coal-ash is the most important, at least when coal of poor quality is used. The ash tends to reduce the hydraulic modulus and the coefficient x.

Tests.

The characteristics of the raw material which determine the complex clinkering

reactions are fineness and composition. Insufficiently fine material results in insoluble residue, and a certain amount of the free lime. The latter also results from the reactions and balances taking place during cooling. An attempt to establish these reactions quantitatively by the discrepancies observed in the application of the proportioning formula is made in the following.

Tests were carried out in a rotary kiln working on the wet process and producing a normal product. The latter fact made it impossible to experiment with extreme proportionings, and fixed the value of the coefficient x for the slurries entering the kiln. With the analyses of the primary slurries known, the volumes required of both to obtain a slurry suitable for the kiln were observed. With these data, together with the specific gravity (d) and water content (a), it is possible to calculate the composition of the raw material, and this is verified by chemical analysis. From the latter, and knowing the loss on ignition, it is possible to calculate the composition of the clinker, termed C, which would be obtained with perfect burning (without free lime or quartz), that is with an ashless fuel and with no losses due to the escape with the gases. From the composition of clinker C the value of x can be determined. The actual clinker (termed E) ejected by the kiln while the latter is being fed with the raw material of the test is the real product with free lime and insoluble residue and is affected by the composition of the coal ash, etc. There may also be some losses on ignition due to calcining deficiencies. It is assumed that calcination is carried so far that these anomalies cease to occur, and the composition which the clinker E would have had can be calculated ; this assumed clinker will be termed clinker E_1, which will correspond to a coefficient $x\,E_1$, which differs from xE precisely to the extent of the calcining imperfections. Moreover $(x - xE_1)$ gives an idea of the effect of the ash and loss of material to the gases.

The tests were as follows. Having prepared two samples of slurry, one with a high and the other with a low carbonate content, their characteristics were determined, calculating on this basis a transfer to give 242 cu. m. of slurry for the kiln with 78 per cent. carbonate. The data are given in the following table, which includes the volumes calculated by means of formulæ (2) and (3).

Slurry	d	a per cent.	$CaCO_3$	Fineness		By Calculation		Actual Volume cu. m.
				900	4,900	V_1	V_2	
High ..	1·67	36·5	79·20	1·8	11·9	0·367	—	89
Low ..	1·62	39·0	77·25	2·4	12·4	—	0·633	153
								242

The chemical analyses of the dry slurries were

	High. Per cent.	Low. Per cent.
Ignition loss	35·0	34·2
SiO_2	14·1	14·8
Al_2O_3	4·1	5·2
Fe_2O_3	1·3	1·5
CaO	44·2	43·1
Unaccounted for ..	1·3	1·2
	100·0	100·0

From these data, by applying the formula for the mixture of raw materials: $\frac{\text{weight of dry high-carbonate slurry}}{\text{weight of dry low-carbonate slurry}} = \frac{14{\cdot}8x + (1{\cdot}65 \times 5{\cdot}2) + (0{\cdot}34 \times 1{\cdot}5) - 43{\cdot}1}{44{\cdot}2 - [14{\cdot}1x + (1{\cdot}65 \times 4{\cdot}1) + (0{\cdot}34 \times 1{\cdot}3)}$.
The weights of both slurries used is $89 \times 1{\cdot}670 = 148{\cdot}6$ tons, and $153 \times 1{\cdot}620 = 247{\cdot}8$ tons. The quantities of dry slurry will be $148{\cdot}6 - \frac{148{\cdot}6 \times 36{\cdot}5}{100} = 94{\cdot}4$ tons of dry high-carbonate slurry and $247{\cdot}8 - \frac{247{\cdot}8 \times 39}{100} = 151{\cdot}3$ tons of dry low-carbonate slurry. Thus $\frac{94{\cdot}4}{151{\cdot}3} = \frac{14{\cdot}8x - 29{\cdot}4}{37{\cdot}0 - 14{\cdot}1x}$ from which $x = 1{\cdot}238$.
The raw material *H* fed in is obtained by applying the law of mixtures to the primary raw materials. The calculation, based on the chemical analysis, gives the results in the column headed *H*.

	Raw material *H* Per cent.	Clinker *C* Per cent.
Loss on ignition ..	34·5	0·00
SiO_2	14·5	22·12
Al_2O_3	4·8	7·33
Fe_2O_3	1·4	2·14
CaO	43·1	64·41
Unaccounted for ..	1·3	1·99
	100·0	100·00

From the composition of *H* the composition of clinker *C*, allowing for the loss on ignition, can be calculated with the results given in the appropriate column. The silicate modulus of $C = 2{\cdot}238$.

The following composition of the experimental clinker E was determined by the analysis of an average sample of the product of the kiln during the experiment.

	Clinker *E* Per cent.	Clinker E_1 Per cent.
Loss on ignition ..	0·3	0·00
SiO_2	23·7	23·77
Al_2O_3	6·8	6·82
Free lime = 0·4 per cent.		
Fe_2O_3	3·5	3·51
CaO	62·7	62·88
Quartz = 0·4 per cent.		
MgO	2·1	—
SO_3	0·8	0·80
Unaccounted for ..	0·1	2·22
	100·0	100·00

By applying the formula to this clinker the corresponding value of $x = xE$ is found. Since the presence of SO_3 has to be allowed for, and discounting the free lime and the quartz in the lime and silica totals respectively, $xE = 2{\cdot}117$. Allowing for the loss on ignition of clinker E, the composition of clinker E_1 is calculated, that is, for the clinker obtained in practice but without calcining defects and without taking into account the free lime and quartz, considering these as if both reacted wholly. Thus the results in the column headed E_1 are obtained, and from these is deduced a value of $x = xE_1 = 2{\cdot}122$.

A comparison of the discrepancies gives the following results. The actual divergence of x is $x - xE = 2{\cdot}238 - 2{\cdot}117 = 0{\cdot}121$. The divergence due to ash and losses to the gases is $x - xE_1 = 1{\cdot}238 - 2{\cdot}122 = 0{\cdot}116$. The divergence by calcining is $xE_1 - xE = 2{\cdot}122 - 2{\cdot}117 = 0{\cdot}005$.

To study further the behaviour of the ash as a disturbing factor in the proportioning of the raw materials the following particulars are required: (1) Coal consumption per ton of clinker, (2) Analysis of the coal, (3) Analysis of the ash. Let Q be the percentage coal consumption and Z the percentage of ash. The proportion of ash included in the clinker is $0{\cdot}01QZ$. If Sz, Az, and Cz are the percentages of silica, alumina, iron oxide, and lime respectively in the ash, the contribution A of each of these oxides to the composition of the experimental clinker is given by equations such as the following, which applies to the silica:

$$As = 0{\cdot}0001QZSz.$$

The following example shows the method of calculation. $Q = 0{\cdot}3$ ton of coal per ton of clinker. The coal contains 18·8 per cent. of volatile substances, 23·5 per cent. of ash, and therefore 57·7 per cent. of stable carbon. The analysis of the ash gave in percentages: Loss on ignition, nil; SiO_2, 37·0; Al_2O_3, 26·1; Fe_2O_3, 18·4; CaO, 8·5; S, 9·2 (in SO_3); MgO, 0·7; and unaccounted for 0·1. Therefore $0{\cdot}01QZ = 30 \times 23{\cdot}5 \times 0{\cdot}01 = 7{\cdot}0$ tons of ash per 100 tons of clinker. The contribution A, the retention $(E_1 - C)$ and the retention per unit contribution $\frac{E_1 - C}{A}$ are as given in the following:

	Contribution	Retention	Retention Per Unit Contribution
SiO_2	2·6	1·65	0·64
Al_2O_3	1·8	−0·51	−0·28
Fe_2O_3	1·3	1·37	1·05
CaO	0·6	−1·54	−2·55
SO_3	0·64	—	—
MgO	0·05	—	—
	6·99		

Conclusions.

The experimental examination of the deviations observed on applying the general formula to normal clinkers leads to the following conclusions: (*a*) Devia-

tions brought about by calcining defects are usually negligible ; (*b*) Deviations due to the combined effect of the coal ash and the escape of dust with the gases of combustion are considerable and so variable that it is essential for the coal to contain little ash, or at least that the quality and quantity of the ash should remain reasonably constant, and that the losses in dust should be small and efficient dust extractors should be used ; (*c*) The apparent retention of the various components of the ash is variable. The following factors may have some bearing on this : Fineness of the raw material, coals of different volatility, the intensity of the draught, and the composition of the ash ; (*d*) The test results do not permit drawing definite conclusions regarding the relative contribution of the ash to the composition of the clinker, unless it is possible to determine accurately the coal consumption and the total loss of dust.

The Efficient Use of Fuel.

The Ministry of Fuel and Power has issued a bulletin (No. 43) entitled " The Furnaceman's Manual," which is intended for distribution to men in charge of furnaces. The bulletin is written in simple language, with the object of giving the men a better knowledge of the theory of combustion and furnace operation in the expectation that they will take a more intelligent interest in their work, with a consequent saving in fuel. The twelve sections deal with the fuels used in furnaces, the principles of combustion and of heating, the burning of solid, gaseous, pulverised and liquid fuels, draught, sources of loss of heat, the loading of furnaces, maintenance of furnaces and the keeping of records. Copies of this and of other bulletins on fuel efficiency are obtainable free of charge from the Ministry at 2, Little Smith Street, Westminster, S.W.1, or any of the regional offices of the Ministry.

Cement Plant for China.

It is announced that Messrs. Edgar Allen & Co., Ltd., of Sheffield, have received a contract totalling £420,000 for two complete cement plants for China. Each plant comprises a raw crushing plant, raw grinding mill, rotary cement kiln, cement mill, packing plant and the auxiliary items, as well as a complete generating station for electricity. Each kiln is to be fired by a British " Rema " unit coal plant, to be made by the British " Rema " Manufacturing Co., Ltd., a subsidiary company of Messrs. Edgar Allen & Co., Ltd. Each works will produce 200 tons of cement a day.

Tables for Calculating Cement and Clinker Compounds and Added Materials.

The following tables and notes, by Mr. C. J. Knickerbocker, are reprinted from our American contemporary, " Rock Products " for September, 1945.

A rapid means of calculation of clinker or cement compounds is given in *Table I*. The columns of values are in the order of their use in the computations.

The equations given are those required by A.S.T.M. Specifications for Portland Cement (C150–44).

TABEL I.

—1— (4.07 CaO)	—2— (7.6 SiO_2)	—3— (6.72 Al)	—4— (1.43 Fe)	—5— (2.85 SO_3)	—6— (2.87 SiO_2)	—7— (0.745 C_3S)	—7a—	—8— (2.65 Al)	—9— (1.69 Fe)	—10— (3.04 Fe)	—11— (1/7 SO_3)
63.0-256.4	19.5-148.2	4.5-30.2	2.0-2.86	1.5-4.27	19.5-56.0	30-22.6	0.1-0.07	4.5-11.9	2.0-3.38	2.0- 6.1	1.5-2.55
.1-256.8	.6-149.0	.6-30.9	.1-3.00	.6-4.55	.6-56.2	31-23.4	.2- .15	.6-12.2	.1-3.55	.1- 6.4	.6-2.71
.2-257.2	.7-149.7	.7-31.6	.3-3.14	.7-4.84	.7-56.5	32-24.1	.3- .23	.7-12.4	.2-3.72	.2- 6.7	.7-2.89
.3-257.6	.8-150.5	.8-32.2	.3-3.28	.8-5.13	.8-56.8	33-25.9	.4- .30	.8-12.7	.3-3.89	.3- 7.0	.8-3.05
.4-258.0	.9-151.2	.9-32.9	.4-3.43	.9-5.41	.9-57.1	34-25.6	.5- .38	.9-13.0	.4-4.03	.4- 7.3	.9-3.23
.5-258.4	20.0-151.9	5.0-33.6	.5-3.57	2.0-5.69	20.0-57.4	35-26.4	.6- .45	5.0-13.2	.5-4.22	.5- 7.6	2.0-3.40
.6-258.8	.1-152.7	.1-34.3	.6-3.71	.1-5.98	.1-57.7	36-27.1	.7- .53	.1-13.5	.6-4.40	.6- 7.9	.1-3.57
.7-259.2	.3-153.5	.2-35.0	.7-3.85	.2-6.26	.2-58.0	37-27.9	.8- .60	.2-13.7	.7-4.56	.7- 8.2	.2-3.74
.8-259.8	.3-154.3	.3-35.6	.8-3.99	.3-6.55	.3-58.3	38-28.7	.9- .68	.3-14.0	.8-4.73	.8- 8.5	.3-3.90
.9-260.0	.4-155.0	.4-36.3	.9-4.14	.4-6.83	.4-58.6	39-29.4	.....	.4-14.3	.9-4.90	.9- 8.8	.4-4.06
64.0-260.5	.5-155.8	.5-37.0	3.0-4.29	.5-7.12	.5-58.8	40-30.2	.....	.5-14.6	3.0-5.07	3.0- 9.1	.5-4.25
.1-260.9	.6-156.5	.6-37.6	.1-4.44	.6-7.40	.6-59.1	41-30.9	.....	.6-14.8	.1-5.24	.1- 9.4	.6-4.42
.2-261.3	.7-157.3	.7-38.3	.2-4.57	.7-7.69	.7-59.4	42-31.7	.....	.7-15.1	.2-5.41	.2- 9.7	.7-4.59
.3-261.7	.8-158.1	.8-39.0	.3-4.72	.8-7.97	.8-59.7	43-32.4	.....	.8-15.4	.3-5.58	.3-10.0	.8-4.76
.4-262.1	.9-158.8	.9-39.6	.4-4.86	.9-8.26	.9-60.0	44-33.2	.....	.9-15.6	.4-5.75	.4-10.3	.9-4.93
.5-262.5	21.0-159.6	6.0-40.3	.5-5.00	3.0-8.55	21.0-60.3	45-33.9	.....	6.0-15.9	.5-5.92	.5-10.6	3.0-5.10
.6-262.9	.1-160.3	.1-41.0	.6-5.15	.....	.1-60.5	46-34.7	.....	.1-16.2	.6-6.09	.6-10.9	.....
.7-263.3	.2-161.1	.2-41.7	.7-5.30	.....	.2-60.8	47-35.4	.....	.2-16.5	.7-6.25	.7-11.2	.....
.8-263.7	.3-161.9	.3-42.3	.8-5.44	.....	.3-61.1	48-36.2	.....	.3-16.7	.8-6.42	.8-11.5	.....
.9-264.1	.4-162.6	.4-43.0	.9-5.58	.....	.4-61.4	49-37.0	.....	.4-16.9	.9-6.59	.9-11.8	.....
65.0-264.5	.5-163.4	.5-43.7	4.0-5.73	.....	.5-61.7	50-37.7	.....	.5-17.2	4.0-6.76	4.0-12.2	.....
.1-265.0	.6-164.2	.6-44.4	.1-5.86	.....	.6-62.0	51-38.4	.....	.6-17.5	.1-6.93	.1-12.5	.....
.2-265.4	.7-165.0	.7-45.0	.2-6.00	.....	.7-62.3	52-39.2	.....	.7-17.8	.2-7.10	.2-12.8	.....
.3-265.8	.8-165.7	.8-45.7	.3-6.15	.....	.8-62.6	53-40.0	.....	.8-18.0	.3-7.27	.3-13.1	.....
.4-266.2	.9-166.4	.9-46.4	.4-6.29	.....	.9-62.9	54-40.7	.....	.9-18.3	.4-7.44	.4-13.4	.....
.5-266.6	22.0-167.2	7.0-47.0	.5-6.43	.....	22.0-63.1	55-41.5	.....	7.0-18.5	.5-7.60	.5-13.7	.....
.6-267.0	.1-168.0	.1-47.7	.6-6.57'	.....	.1-63.4	56-42.2	.....	.1-18.8	.6-7.77	.6-14.0	.....
.7-267.4	.2-168.7	.2-48.3	.7-6.71	.....	.2-63.7	57-43.0	.....	.2-19.0	.7-7.94	.7-14.3	.....
.8-267.8	.3-169.4	.3-49.0	.8-6.85	.....	.3-64.0	58-43.7	.....	.3-19.3	.8-8.11	.8-14.6	.....
.9-268.2	.4-170.2	.4-49.7	.9-7.00	.....	.4-64.3	59-44.5	.....	.4-19.6	.9-8.28	.9- .9	.....
66.0-268.6	.5-171.0	.5-50.4	5.0-7.15	.....	.5-64.6	60-45.2	.....	.5-19.9	5.0-8.45	5.0-15.2	.....
.1-269.0	.6-171.7	.....	.....	.....	.6-64.9	61-46.0	.....	.....	.....	.....	.....
.2-269.4	.7-172.5	.....	.....	.....	.7-65.1	62-46.7	.....	.....	.....	.....	.....
.3-269.9	.8-173.3	.....	.....	.....	.8-65.4	63-47.5	.....	.....	.....	.....	.....
.4-270.3	.9-174.0	.....	.....	.....	.9-65.7	64-48.3	.....	.....	.....	.....	.....
.5-270.7	23.0-174.8	.....	.....	.....	23.0-66.0	65-49.0	.....	.....	.....	.....	.....

(C_4S) $4.07CaO - (7.6SiO_2 + 6.72Al_2O_3 + 1.43Fe_2O_3 + 2.85SO_3)$
(C_2S) $2.87SiO_2 - 0.754C_3S$
(C_3A) $2.65Al_2O_3 - 1.69Fe_2O_3$
(C_4AF) $3.04Fe_2O_3$
(C_4F) $(1.7Fe_2O_3 + 2.1Al_2O_3 - (4.767Al_2O_3$

TABLE II.

A	B	C	D	E
10	2.8	18	30	20
20	5.7	36	60	40
30	8.5	54	90	60
40	11.4	72	120	80
50	14.2	91	150	100
60	17.0	109	180	120
70	19.9	127	210	140
80	22.7	145	240	160
90	25.5	163	270	180
100	28.4	181	300	200
110	31.2	199	330	220
120	34.1	217	360	240
130	36.9	235	390	260
140	39.8	253	420	280
150	42.6	271	450	300
160	45.4	290	480	320
170	48.3	308	510	340
180	51.1	326	540	360
190	54.0	344	570	380
200	56.8	362	600	400

The following example illustrates the operation :

SiO_{22}, 20·8 per cent. ; Al_2O_3, 6·7 per cent. ; Fe_2O_3, 2·7 per cent. ; CaO, 65·6 per cent. ; SO_3, 1·8 per cent.

	C_3S	
	267·0 — #1	158·10 — #2
(—)	212·1	45·00 — #3
		(+) 3·85 — #4
	54·9	5·12 — #5
	(C_3S)	
		212·07
	C_2S	
	59·7 — #6	40·70 — #7
(—)	41·4	(+) 0·68 — #7a
	18·3	41·38
	(C_2)	
	C_3A	(C_4AF)
	17·8 — #8	8·2 — #10
(—)	4·6 — #9	(C_4AF)
	13·2	(#*I* = *Table I*, Column I, etc.)
	(C_3A)	

The tables can be readily extended to include compositions not listed. The computations can be checked by comparing the total of the oxide analysis with the total of the four determined compounds and the $CaSO_4$ value in column 11.

Table II is convenient for reference when it is necessary to calculate the amount of material to add to a feed entering the grinding units. The table is based upon the addition of 0·01 per cent. solid by weight to the feed. The addition is per minute of operation, which is a convenient addition or checking interval. Several states in which additions are commonly used are given.

The dry solids weights for the table are determined from the equation

$$\text{Grammes per minute} = \frac{\text{(barrels per hour.) (376) (454) (Per cent. addition)}}{\text{(60) (100)}}$$

The dry weight values are converted to volume of 15 per cent. solution on the basis of the mean specific gravity of the substances commonly used in this state.

In *Table II*, *A* is the mill feed rate in barrels (376 lb.) per hour ; *B* gives the grammes per minute dry solids addition for 0·01 per cent. by weight ; *C* gives the addition in millilitres per minute of a solution containing 15 per cent. solids that will result in an 0·01 per cent. solids addition. *D* is the addition in millilitres per minute of a solution containing 15 per cent. solids that will result in an addition of one ounce of solids per barrel of feed. *E* is the addition in millilitres per minute of a liquid of 0·90 specific gravity that will result in an addition of 0·01 per cent. by weight.

The general formula may be reduced for the respective columns as follows: *B*—Grammes per minute equals $0{\cdot}284A$, *C*—Millilitres per minute equals $1{\cdot}81A$ *D*—Millilitres per minute equals $3{\cdot}0A$, *E*—Millilitres per minute equals $2{\cdot}0A$.

Example. To add 0·025 per cent. solid material as a 15 per cent. solution to a feed being ground at the rate of 135 barrels per hour. From *Table II*, column *C*, $244 \times 2{\cdot}5 = 610$ millilitres per minute, or $1{\cdot}81 \times 135 \times 2{\cdot}5 = 610$ millilitres per minute. The tabulated values, as noted, are additions to the feed and not amounts that will result in the product containing the indicated percentage. In view of the fact that the quantity of addition used is generally based upon the requirements of performance tests made on the product, the values are adequate for the intended purpose.

In cases in which an addition is to be made that will result in a definite percentage content of the product, it is convenient to use the equation $A = A'F + \frac{(A'F)^2}{F - A'F}$ where A = pounds addition in time T, F = pounds feed in time T, A' = per cent. addition desired in the product, expressed as a decimal.

Example.—The feed is 50 barrels (18,800 lb.) per hour. The product is to contain 1·3 per cent. addition.

$$A = (0{\cdot}013 \times 18{,}800) + \frac{(0{\cdot}013 \times 18{,}800)^2}{18{,}800 - (0{\cdot}013 \times 18{,}800)} \text{ or, } 247{\cdot}6 \text{ lb. per hour}$$

addition. Check: $\frac{247{\cdot}6}{18{,}800} + 247{\cdot}6 = 0{\cdot}013$, or 1·3 per cent.

Cement Production in the United States.

THE production of Portland cement in the United States during the month of February, 1946, was, according to the U.S. Bureau of Mines, 9,250,000 barrels. This is an increase of 12 per cent. on the production in February, 1945. The industry was, however, still only producing at the rate of 50 per cent. of its total capacity, compared with 29 per cent. in February, 1945.